Remote and surface X-ray experiments of small bodies

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内容

・X線法による小天体の観測から得られるもの

リモート：太陽X線励起XRFによる天体の平均的な主要元素組成

C/D型小天体では基本的にC-chondrite

Al/SiからCIorCMorCV/CM　CRなどの区別

Sの欠乏の程度

太陽活動に強く依存する（NEAR，Hayabusa）

表面：　XRF，XRDによる分析

加工なしでも，表層の分析可能，但し簡易なブラシは有用

線源搭載不能

小型X線管　→　XRFの原子番号制限，角度

Debye法　preparation必要

Raue法　non-preparationで可　→◎

大部分の主要元素，鉱物，粒径などをその場で分析

サンプルリターンでは破壊，水質変成の恐れあり

・Instrumentation：

・リモート法

はやぶさ等の実績

長期間の航行と機上較正

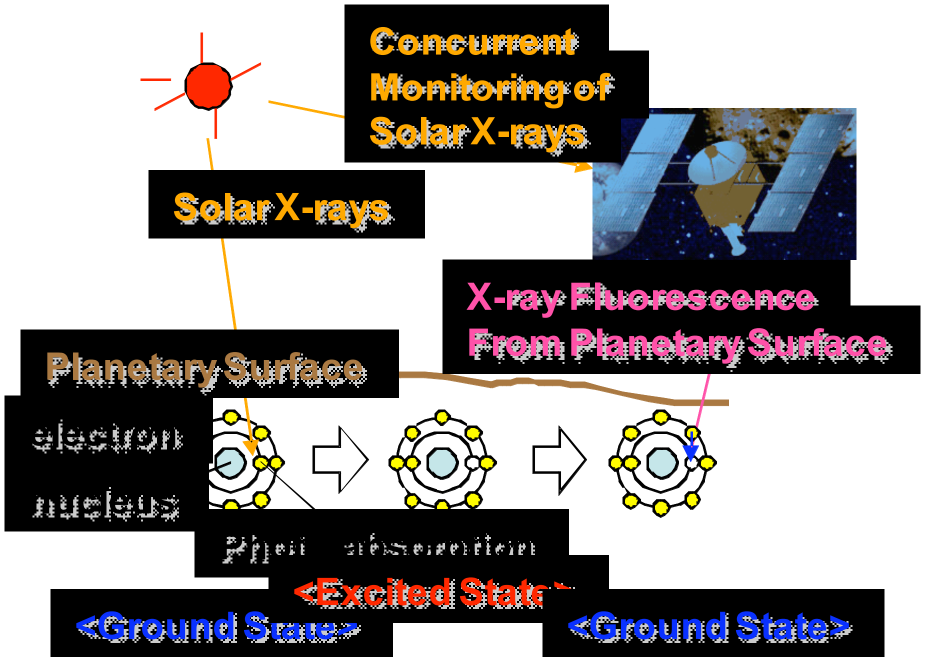
・表面法

Remote X-ray Method：NEAR-Shoemaker, Hayabusa

Irradiation of solar X-rays into the atmosphere-free planetary surface excites X-rays characteristic of elements , especially for major rock-constituent elements.

Spectroscopy of these X-rays (remote XRF) allows us to determine major elemental composition of the uppermost (~10 micrometer) surface with concurrent observation of solar X-rays.

Remote XRF is highly dependent on solar activity. Launch in 2014 does not seem a good timing for this method (arrival at solar minimum!).



Major Element	XRF Energy	Solar Activity	
		Quiet	Flare
Mg	[illegible]	[illegible]	○
Al	[illegible]	○	○
Si	[illegible]	○	○
S	[illegible]	△	○
Ca	[illegible]	× [illegible]	○
Ti	[illegible]	×	○
Fe	[illegible]	×	○

C/D-class asteroids are considered as carbonaceous chondrite meteorites. Major elemental ratios are basically "chondritic." Total error by remote XRF is about 10% of the elemental abundance, so it is not easy (but maybe possible) to discriminate the type of chondrites (between CI, CM, CV/CO, CR, …).

Detection of some depletion of sulfur abundance at the surface is likely for C-chondrite, which informs some kind of surface process occurs (melting, micro-impacts, …)

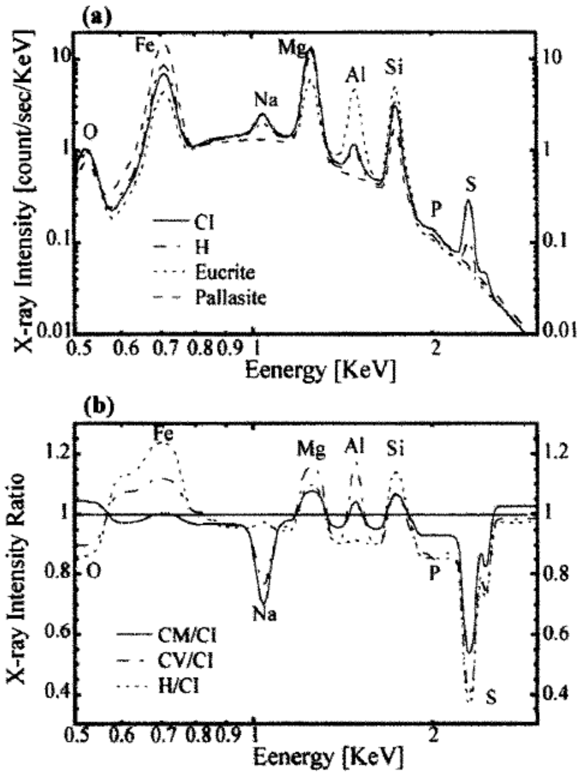


Fig.1 The calculation of x-ray spectra of meteoritic materials excited by solar x-ray in quiescent condition. (a) The x-ray spectra and (b) the ratio normalized by CI composition.

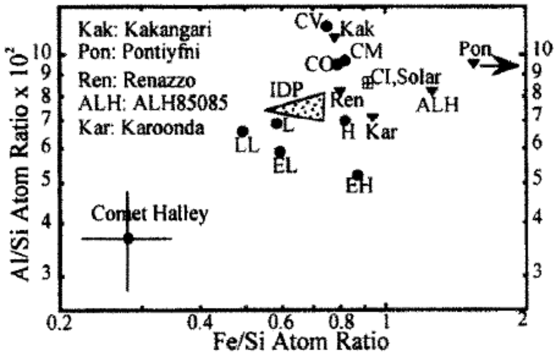
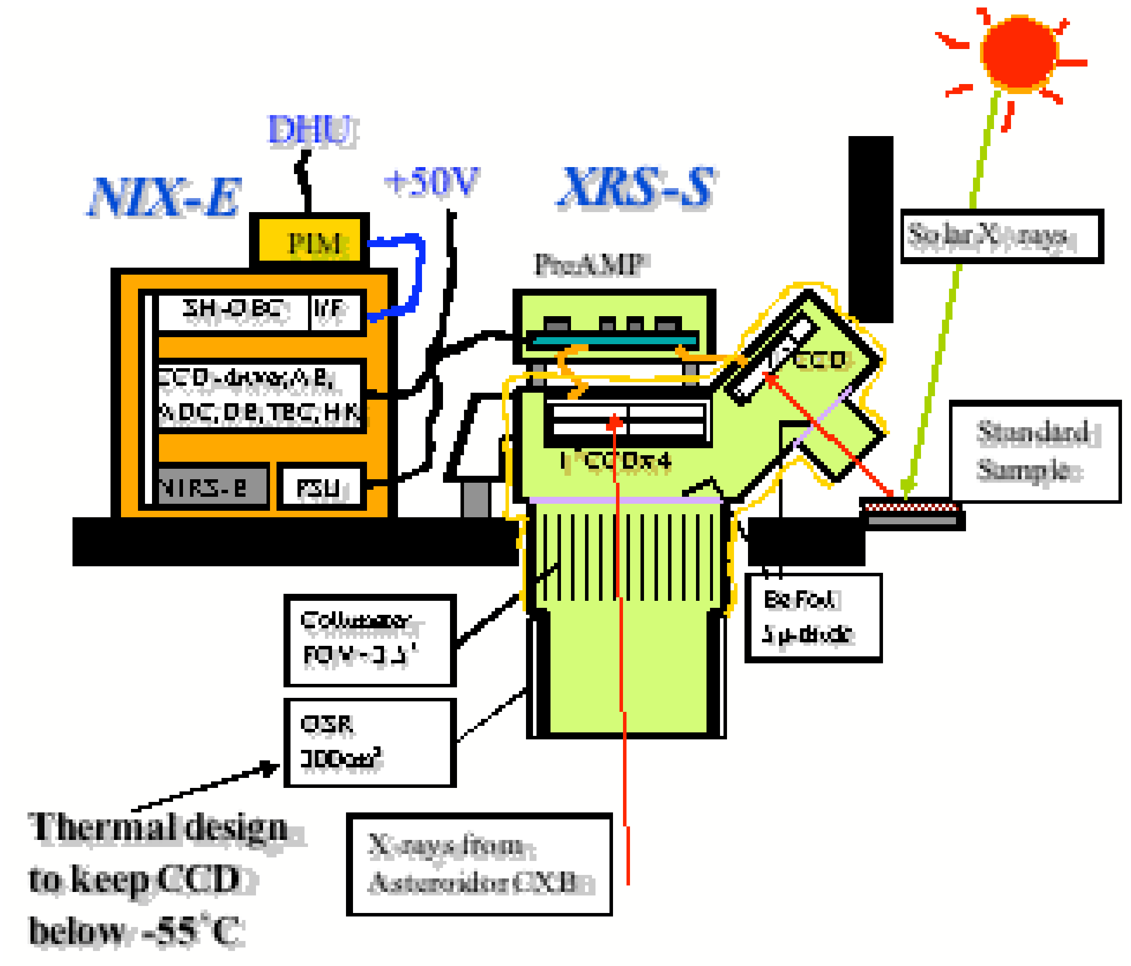


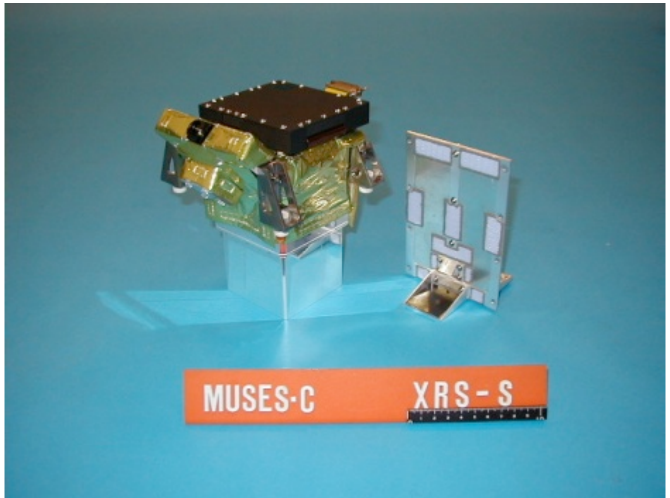
Fig.2 The variation in Fe/Si and Al/Si among the chondrites, IDPs, P/Halley, and the Sun (modified from Scott and Newsom, 1989; Taylor, 1992).

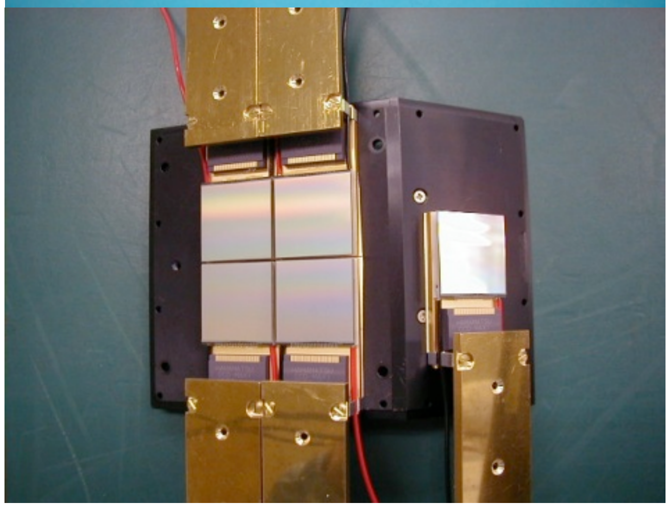
[Okada et al. ASR(2000)

XRS onboard Hayabusa

XRS is a CCD-based X-ray fluorescence spectrometer.
4 CCD is used for detection of asteroid X-rays and a single CCD is for XRF off the standard sample.





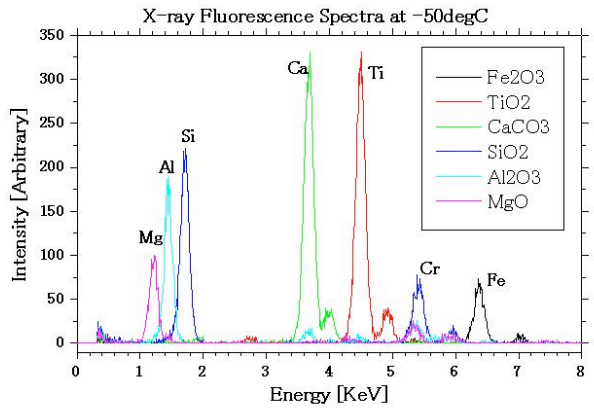


Example of X-ray detection by CCD

CCD-based XRS has energy resolution high enough to discriminate XRF of Mg, Al, Si, and other major elements when sufficient counts of X-ray photons are observed.

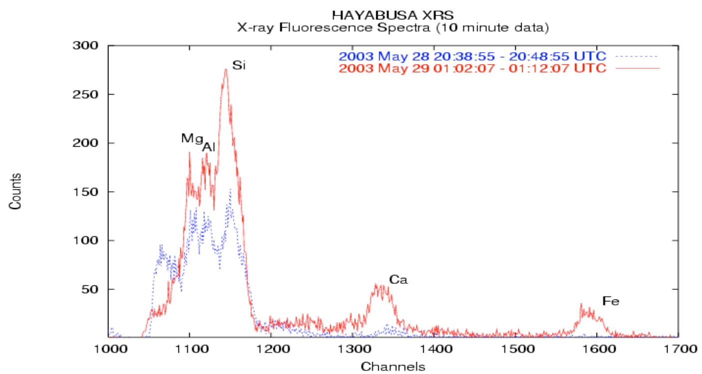
Pre-Flight (in Laboratory)

Okada et al. Adv. Geosci., PS3 (2006)



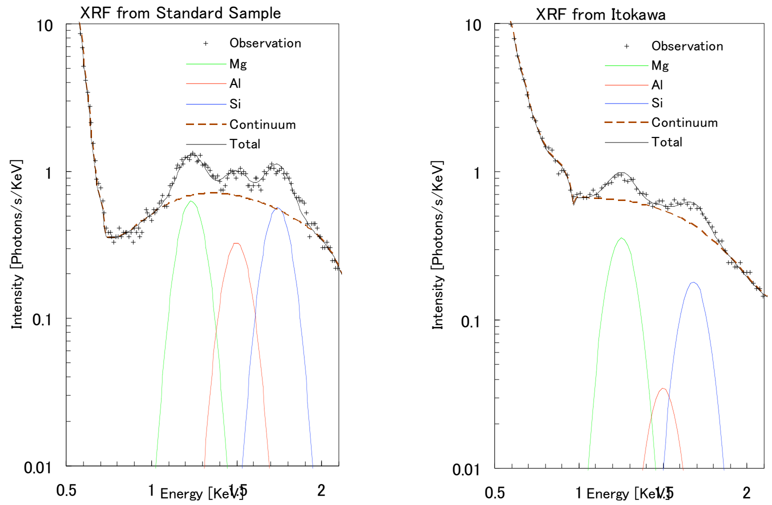
Cruise Phase (Solar Flares)

Okada et al. Adv. Geosci., PS3 (2006)



Touchdown phase (Solar minimum)

Okada et al. Science (2006)



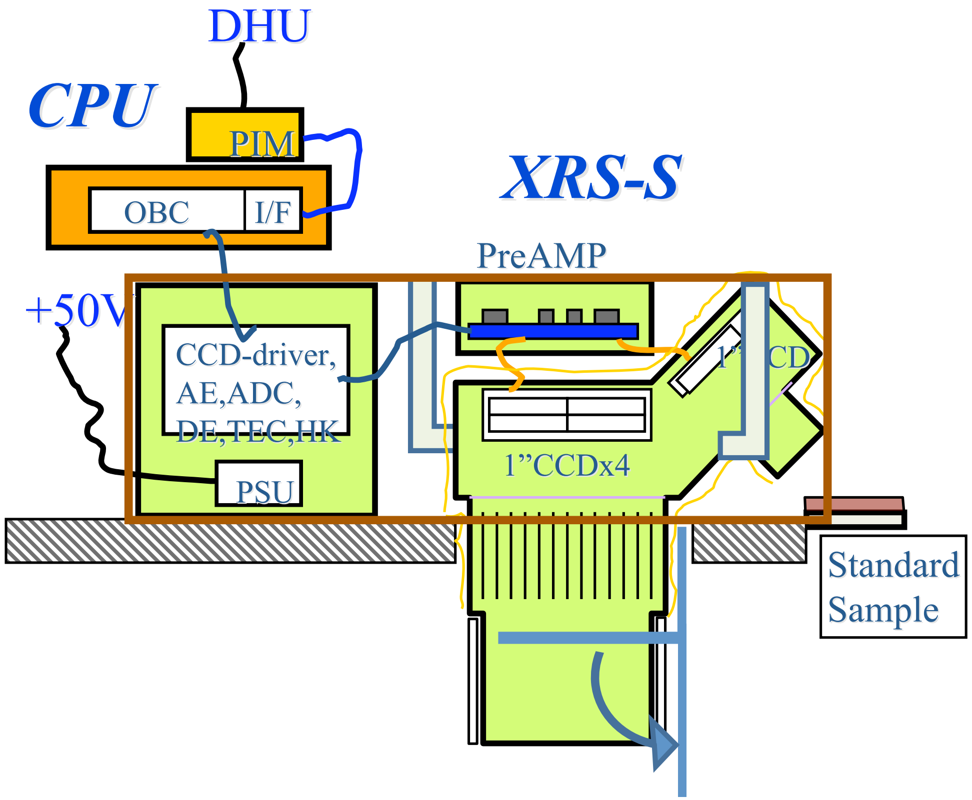
XRS onboard Hayabusa follow-on mission

Thermal design:

Cold part (including CCDs) is to be surrounded by thermal shield case to avoid radiation inside the spacecraft.

Door for radiation shield and energy calibration:

A longer cruising phase needs more radiation tolerance. Onboard energy calibration using Fe55 source is important. Thus XRS should add a door for those purposes



Surface X-ray Method：

Onboard X-ray source excites X-rays characteristic of elements , especially for major rock-constituent elements. It also scatters (diffracts) into the directions restricted by crystal structures.

< X-Ray Fluorescence >

Spectroscopy of these X-rays (in situ XRF) allows us to determine major elemental composition of the uppermost (~10 micrometer) surface by comparing X-ray spectroscopy of standard sample.

Range of detected atomic number (Z) is dependent on energy of the primary X-ray source. For E< 8kV, Z=11~26 (e.g., Na, Mg, Al, SI, S, K, Ca, Ti, Fe).

< X-Ray Diffraction >

Detection of X-ray diffraction pattern (and its energy) allow us to determine major crystal structure (d-spacing), using a 2D-X-ray detector.

Debye method needs sample preparation, while un-prepared sample can be analyzed by Laue method.   Without complex sampling/processing system, Laue method is desirable.

XRD/XRF + Macro Imager

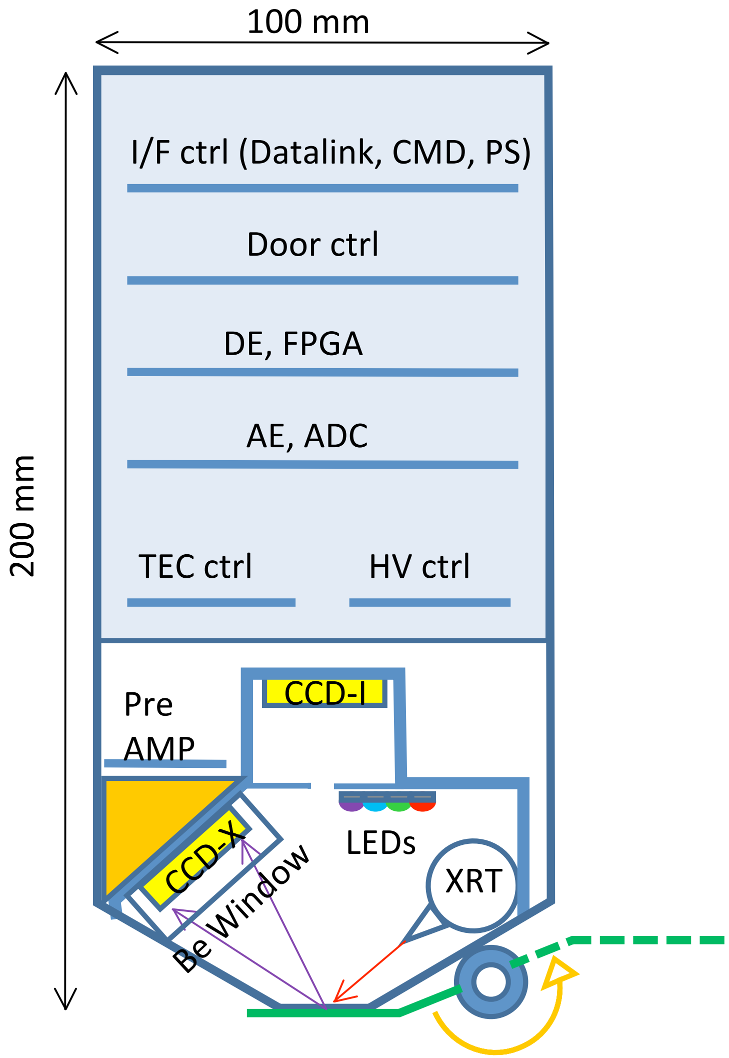
Chemical/mineralogical/morphological measurement for unprepared samples

Science Objectives:

XRD: mineralogy, organics, ices, hydrated/aqueous processes (Laue method)
XRF: elemental composition (Z=11~26), rock-types
Image: particle size, roughness, UV fluorescence of organics?

Performances:

Mass: < 2kg, Power: <6W
Size: 100 x 100 x 200 mm
Data: 3~4MBytes per sample (Image, XRD, XRF)
1 of 2 CCDs are operated:
CCD-I for imagery with LED (UV, 450,750,950nm)
CCD-X for XRD/XRF with XRT (<10KeV)



Sample (5mm region, XRT spot is 1mm)
Door close: used for calibration

Problems:

HV required: up to 10KV
Peltier or Stirling cooler of CCD to -30degC (depending on CCD type)